

Informational Masking and Trained Listening

Undergraduate Honors Thesis

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of Bachelor of the Arts

by

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Abstract:

Informational masking occurs when a sound is more difficult to hear than we can predict by simply measuring the power in the sound and the power in the masking noise. It often occurs when one speech sound occurs in the presence of one or more competing speech sounds (Kidd, et al., 2008). Oxenham, et al, (2003) found that trained musicians seem to be less affected by informational masking than non-musicians. The hypothesis states that trained listeners in general, and not only musicians, are less susceptible to informational masking. For this study, listeners were divided into four groups. Group one was comprised of listeners with no formal musical training. Group two contained trained musicians who either studied or performed music at the college level but did not pass a musical interval recognition test. The third group consists of trained musicians who passed the interval test with a score of 90% or greater. The final group contained Morse code listeners with a code speed of twenty words per minute or greater. The maskers were eight component tone bursts. The first condition was the tone with no masker to determine the listener's threshold in quiet. In the second condition the tone is played in a "twinkling masker." On each burst the masker tones change in frequency but the frequency of the target tone remains constant. This is called the multiple burst different (MBD) masking condition. In the third condition a multiple burst same masker (MBS) is used. Here eight tones selected for the first burst are repeated over the remaining seven bursts. This means that the frequency of the eight masking tones and the target remain constant. The level of the tone that can be detected in the MBS or MBD masker is the masked threshold. Generally, the

masked threshold for the MBS condition is much higher than that for the MBD condition. The level of informational masking was found by finding the difference between the MBD and MBS masking conditions. The trained musicians who passed the interval test performed better on average than any other group on the informational masking task. The trained musicians who did not pass the interval task did slightly better than the control group. The Morse code listeners performed worse than the control group. This disproved the hypothesis that all trained listeners and not just musicians are less prone to informational masking.

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I. Introduction and Literature Review

The term masking typically refers to energetic masking. Energetic masking typically takes place in the peripheral auditory system. An example of energetic masking occurs when one tone blocks out or reduces another tone's audibility. Masking can refer to the reduction of any tone or tones due to the presence of another tone or tones (Berg, 2005). Another type of masking is informational masking. This experiment will focus on informational masking. Informational masking can most clearly be defined by what it is not; it is not energetic masking taking place in the peripheral auditory system, but masking that takes place beyond the cochlea, or in the central auditory system. The most informational masking tends to be observed when the competing signals are too similar or confusing (Kidd, 2003). Competing speech sounds are an example of confusing competing sounds. The amount of informational masking can be approximated by taking the total amount of masking that occurs and subtracting both the amount of energetic masking and other noise such as internal physiological noise from the total. Unfortunately, no model exactly predicts the amount of energetic masking that is taking place at the time (Kidd, 2003). Psychoacoustic models are typically used as a reference to estimate the total amount of energetic masking taking place (Kidd, 2003).

This experiment was based on a study conducted by Oxenham et al (2003). They found that ear trained musicians tend to show lower levels of informational

masking than non-musicians. This idea makes sense because expert musicians must listen analytically and break apart the components of a signal. This experiment hopes to extend that idea by examining other groups of expert trained listeners such as Morse code operators. Morse code listeners were selected to represent another group of expert listeners because part of their training often involves listening to code in background noise. They also listen to one frequency of Morse code embedded in other frequencies of Morse code. They need to be able to dissemble a sound and pay attention to only important components like expert musicians.

This study is not the first auditory study to use Morse code listeners either. Montnemery and Harris also used Morse code listeners. In their study, they tested how well Morse code listeners could pick out code when the signal was out of phase with the masker presented to one ear or both. The Morse code presented an opportunity to test comprehension of a noise without using a signal as complex as speech. Washburn also used Morse code listeners in his study. Listeners were asked to listen to Morse with different maskers playing out of phase or with 3d cues. The aim was to find which type of masker was less tiring for the Morse code operators.

Literature Review

Informational masking is thought to be a result of different kinds of processing beyond the auditory peripheral system including perceptual grouping, source segregation, attention, memory and other general cognitive processes (Kidd, 2003). Motivation to put effort into performing well on the listening task and

understanding what the task asks for are also important factors (Kidd, 2003).

Although there is still debate over whether or not informational masking is a separate entity from the cognitive processes mentioned above, many scientists have found evidence that supports that it is indeed a separate entity.

Carhart et al. (1969) conducted an experiment that tested how different maskers affected incoming speech signals. Some of the masker types they considered included multi-tone maskers and speech sound maskers. Carhart (1969) wanted to see which type most effectively masked speech signals. Both monaural and binaural listening were taken into consideration. He found that using a speech masker rather than a noise masker had a much larger effect than expected for either monaural or binaural listening. He termed this finding “perceptual masking”. Carhart’s findings suggested that some sort of masking was occurring beyond the cochlea even though most audiologists at the time thought that the cochlea was the main site where informational masking took place. Watson and Kelly also found that masking increases with the listener’s uncertainty. They more masking occurring than they mathematically predicted. More masking occurred than expected even when their procedures were standardized (Kidd, 2003).

Lutfi et al. (2003) examined two different mathematical models, the fixed weight hypothesis and the variable weight hypothesis. They predicted levels of informational masking. These models are important because they try to describe masking in variable, real world conditions. The fixed weight hypothesis predicts that the slopes of the psychometric function will be shallower for the multi-tone

maskers than they will be for the broadband noise. It also predicts that the slopes of the psychometric functions will change according to how many tones played in the multi tone masker. The variable weight hypothesis predicts the same behavior for the slopes, but changes in the upper asymptote. This is expected because the listener is supposedly listening as though through two different filters for the two conditions instead of comparing the two presentations through the same filter.

Lutfi used goodness of fit to determine which hypothesis most accurately described the informational masking produced in the experiment. Neither hypothesis quite predicts the pattern of informational masking generated during the experiment. The fixed weight hypothesis predicts thresholds fairly well when variables are held constant but fails in this experiment when more than one parameter is being examined. The variable weight hypothesis seems to more accurately describe the informational masking observed in this experiment, but not perfectly. Most listeners produced results consistent with the variable weight hypothesis but a small group was more consistent with the fixed weight hypothesis. No age or gender differences explain the divide in results. Overall, the variable weight hypothesis seems to more closely predict informational masking but still does not quite capture the results observed. Lutfi's findings are applicable to this experiment because inexplicable patterns of participant performance surfaced in this study too.

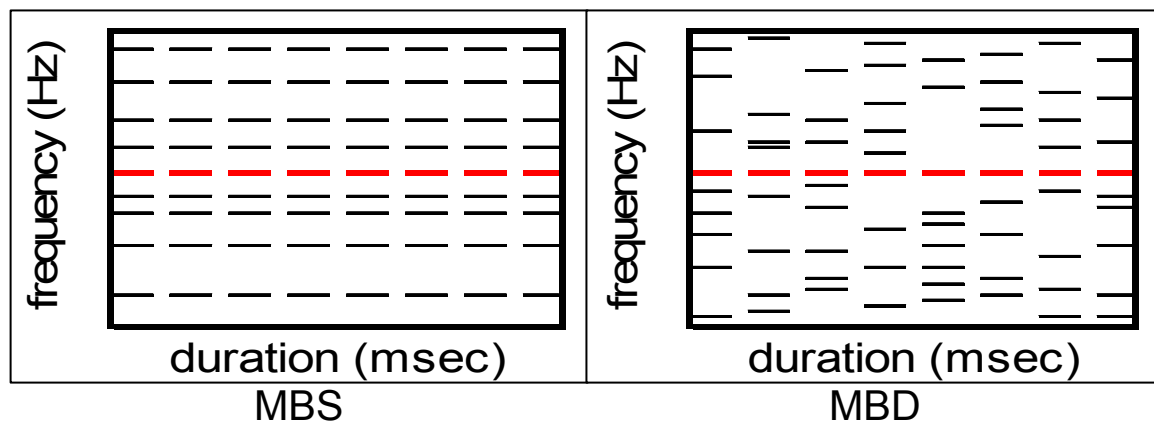
Oxenham et al (2003) wished to see if expertly trained musicians would be as strongly affected by informational masking as non-musicians. Musicians are able to

hear out tones when they are playing despite similar competing sounds. In order to test this idea, Oxenham compared the results from a group of expert musicians to a group of non-musicians.

All of the participants in Oxenham's study had normal hearing. The subjects were divided into two groups. Expert musicians represented one group and the other contained non-musicians. Both groups were balanced for gender. All of the participants filled out a questionnaire regarding their previous musical training. None of the non-musicians had practiced music past the age of ten and only one could read music. Oxenham's expert musician group was pooled from undergraduates and graduate students majoring in music as well as adult professional musicians. They all took two semesters of ear-training courses at some point during their musical education. They all actively play and practice music currently. The musician group had to pass a musical interval recognition test with 90% accuracy in order to qualify as a musician. The test involved two different notes played and the participant had to decipher how far apart the two tones were on a musical scale. Those who did not pass with a 90% did not meet the inclusion criterion for the expert musician group.

The target stimulus that Oxenham used was a 1000 Hz tone comprised of 8 different bursts with a 0ms pause in between. This series of bursts lasted for a total of 60 ms. He used two different kinds of maskers. Both maskers consisted of eight bursts of eight different frequencies. These eight masking bursts played in succession with a 0ms pause in between. One was a multiple burst same masker

(MBS) that played eight masking tones that remained constant for all eight of the bursts. These eight masking tones were randomly selected from a range of frequencies from 200 to 5,000 Hz. A 400 Hz wide protected region surrounded the 1000 Hz tone to make sure the masker was not too similar to the target tone. The MBD masking condition used the same stimulus tone as the MBS condition. The MBD masker is different than the MBS masker because a different set of masking frequencies plays for each of the eight bursts. This masking condition is referred to as a twinkling masker because the masking tones fluctuate so much around the target tone. Refer to figure A1 below for a visual representation of the masking conditions.

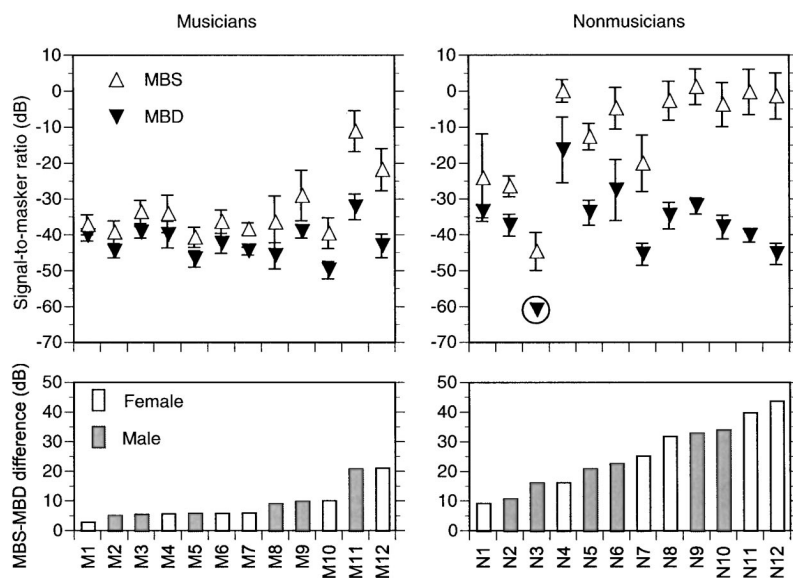


A1

This figure visually represents the MBS and MBD masking conditions. The red line represents the 1000 Hz target tone. This graph was produced by Dr. Evelyn Hoglund, PHD.

In the MBD condition, the masker and the tone are perceptually grouped as originating from two different sources because they are perceived to be different lengths. This perceptual cue provides a release from masking. It helps the listener hear the signal in the MBD masker at a lower threshold than the MBS masker.

The trained musician group averaged significantly less informational masking than the non-musician group did. However, individual variability was observed once again. Refer to figure A2 below. A few of the non-musicians performed better than the musicians. No explanation was provided for that phenomenon.



A2

These graphs were generated by Oxenham (2003). The two graphs on the left display results from the trained musicians. The two graphs on the right show results from the non-musicians. The smaller thresholds indicate better participant performance on the task. The shaded bars were female participants; the un-shaded bars were males.

Oxenham's findings prompted the idea for this experiment. This experiment examines whether only expert musicians are immune to informational masking or if other groups of expert listeners show similar immunity. The more listening training a person has, the better they are expected to perform. Lower threshold differences

between the MBS threshold and MBD threshold are expected to be smaller for both the expert musician group and the expert Morse code listener group.

II. Methods:

Friends and acquaintances were recruited for this study. All of the participants were given an audiometric screening test via air conduction. They listened through TDH headphones. All of the participants had normal hearing at 1000 Hz. Some of the older participants had a hearing loss in the higher frequencies. All of the participants filled out a consent form and an ethnographic survey. The participants' ages ranged from nineteen to sixty-seven. The listeners were divided into four groups for this study. Six non-musicians with no formal auditory training of any type served as the control group. The second group contained five musicians who performed at the college level but could not pass an interval recognition task with a score of 90% or better. The third group was made of four expert musicians who did pass the interval test with a score of 90% or better. The fourth group contained three expert Morse code listeners. The groups were not balanced for gender. The non-musician group was comprised of only two females and four males. The non-expert musician group had two females and three males. The expert musicians were comprised of two females and two males. All three of the Morse code listeners were men. Both the trained musician group and the expert Morse code operator groups had much older participants on average than the other two groups. The first two groups had participants who were between nineteen and twenty-two years old. The expert musician group had participants who ranged from twenty-one to sixty-seven years of age. All three of the men in the Morse code group were middle aged. Refer to table 1 below for a visual spread of group demographics.

Table 1

	Mean age	Total #	# of males	# of females
Non Musicians	20.02	6	4	2
Inexpert Musicians	20.60	5	3	2
Expert Musicians	37.75	4	2	2
Morse Code Operators	59.00	3	3	0

The table above shows the average age of each group of participants. It also shows how gender was distributed in each group.

All of the listeners reported any formal or informal musical training they had. Any participants with formal music training at the college level were given an interval recognition test similar to Oxenham's. The task involved determining how far apart two tones were on a musical scale. The tones all ranged from one to eleven semitones apart. The participants were allowed to listen each condition as many times as they wanted to until they answered. They were also allowed to draw piano keys or a musical staff if they chose to do so. They could take the test twice if they did not pass the first time. Passing the test with a 90% or greater was the inclusion criterion for the expert listening group. This criterion is consistent with Oxenham's inclusion requirements for the expert musician group. Some of the individuals from the non-musician and inexpert musician group who showed very low threshold differences also took the test after they finished running the experiment.

The Morse code group contained highly trained Morse code listeners who can hear entire phrases instead of individual letters as they interpret code. They took a code speed test and had to score a code speed of 20 words per minute or greater in order to qualify for the experiment. This code speed score was arbitrarily chosen because it was the code speed required to obtain an amateur radio license.

It may or may not be equivalent to the expertise required to pass an interval recognition task with a 90 % or greater like the expert musicians.

The listeners sat in a sound-treated room facing a computer screen. They wore a set of Sennheiser headphones that played sounds that corresponded to a visual display on the computer screen. The screen showed two boxes that light up one at a time. A sound played simultaneously as the boxes lit up. The listener was asked to click on the box that lit up as the target tone played. There was a bar at the bottom of the screen that provided feedback as to whether the listener's response was correct or not. It also indicated when the measurement period ended and the testing period began. The listener wrote down the mean and standard deviation in a journal after each trial. A graphic display of the listener's responses also appeared at the end of each trial.

The participants listened to three conditions in the same order. Each condition played about fifty trials per block. Each block was repeated five times before the participant moved on to the next condition. Each participant listened to a total of five to ten blocks per condition. In the first condition, the 1000 Hz tone played in isolation in order to determine the listener's threshold in quiet. In the second condition, a multiple burst same masker (MBS) is used. Here eight tones selected for the first burst are repeated over the remaining seven bursts. This means that the frequency of the eight masking tones and the target remain constant and play for an equal duration. In the third condition, the tone is played in a multiple burst different (MND) masker. The MBD is sometimes referred to as a "twinkling

masker.” On each burst the masker tones change in frequency but the frequency of the target tone remains constant. The perceived duration of the masker components is much shorter than the duration of the target signal and it sounds like the short masking bursts twinkle around the longer target tone. The level at which the 1000 Hz tone can be detected in the MBS or MBD masker is the masked threshold. Typically, the masked threshold for the MBS condition is much higher than that for the MBD condition. Refer back to figure A1 for a visual representation of the MBS and MBD masking conditions.

The perceived discrepancy in time for the MBD masking condition creates a release from masking. This occurs because the differences in length are a cue to the ear that the two sounds came from different sources according to source segregation laws. The threshold for the MBD condition was subtracted from the threshold for the MBS condition. Please refer to graphs below for a visual demonstration.

III Results:

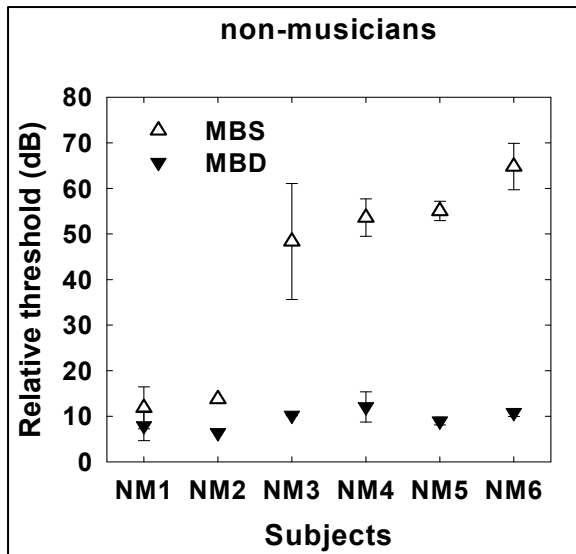
This experiment replicated Oxenham's finding that ear trained musicians show lower levels of informational masking than untrained listeners on average. This experiment also sought to test whether or not other expert listeners such as Morse code listeners also display some reduction in informational masking. On average, the ear trained musicians performed better than all of the other groups. Their average difference of informational masking between the MBS and MBD conditions was about 20 dB. The other groups averaged a difference of about 30 dB. This was expected. The Morse code group, however, did not perform as well as the trained musicians. They did even worse as a group than the untrained control group. Several factors may have lead to this result.

The following information pertains to the first four graphs below. Each figure along the abscissa represents an individual listener belonging to one of four groups. Each title at the top of the graphs announces which group the listeners belonged to. The zero on the Y-axis in the first set of graphs refers to the listener's threshold during the quiet condition. The next point up refers to the listener's threshold in the MBD masking condition. The top point refers to the listener's threshold in the MBS masking condition. The distance between the MBS and MBD thresholds illustrate the threshold differences between the two conditions. These graphs show whether a low threshold difference between the MBS and MBD is due to the MBS threshold lowering and approaching the MBD threshold as expected or if it occurs because the MBD is unusually elevated and approaching the MBS

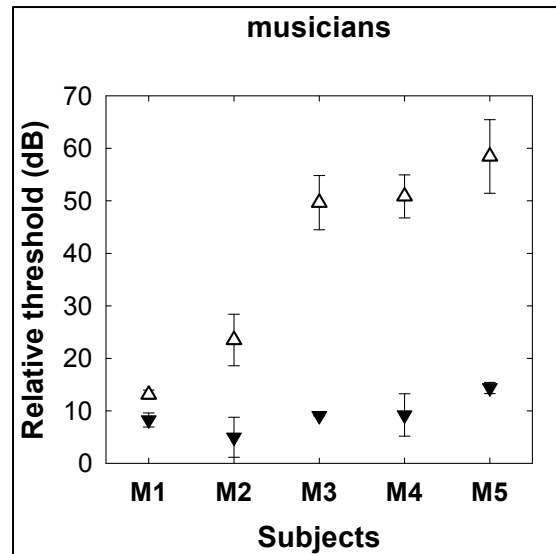
threshold. This is the case for subject # EM2 from the trained musician group.

When interpreting the results, the reason for lower threshold differences needs to be taken into consideration.

A3

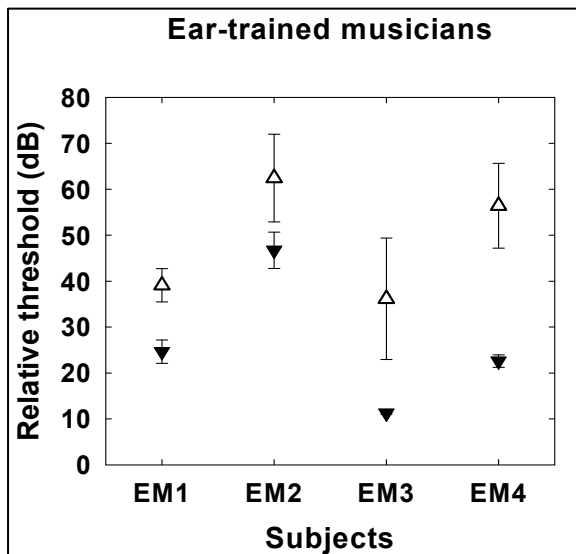


A4

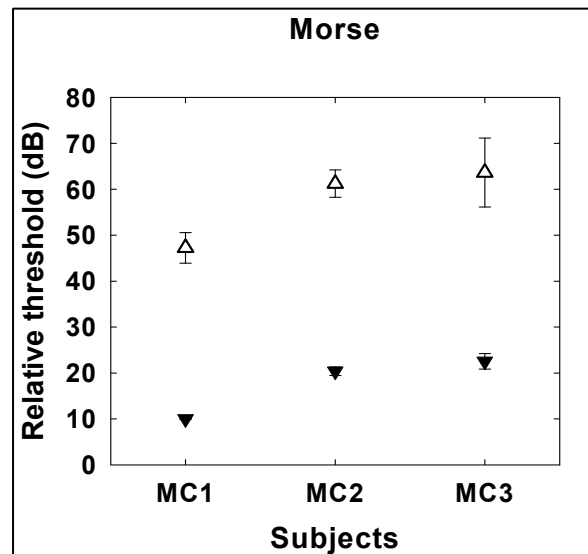


The two graphs above refer to the untrained listening groups. The 0 on the Y axis represents the listener's threshold in quiet. The filled arrow is the MBD threshold and the unfilled triangles represent the MBS threshold. The distance between the two is the most critical information in the graphs above.

A5



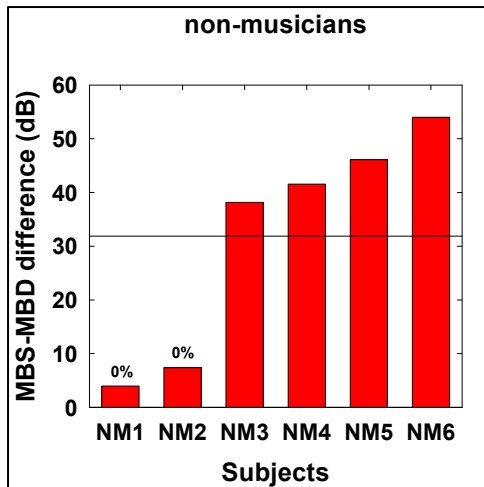
A6



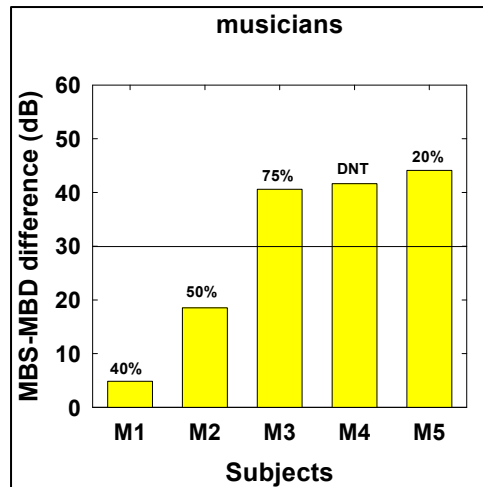
The two graphs above refer to the expert listening groups. The 0 on the Y axis represents the listener's threshold in quiet. The filled arrow is the MBD threshold and the unfilled triangles represent the MBS threshold. The distance between the two is the most critical information in the graphs above.

The graphs below show the same information as the graphs above, but only the difference between the MBS and MBD thresholds are shown. Each bar on the graph represents an individual listener.

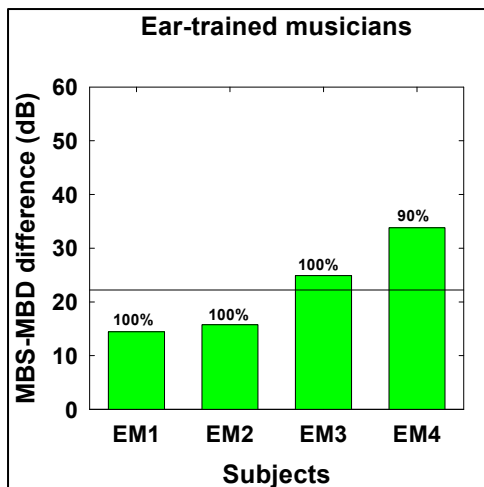
A7



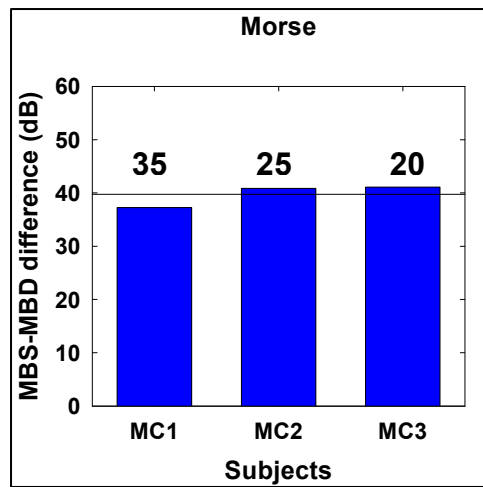
A8



A9



A10



It is important to note, however, that there was a great deal of individual variability in all of the groups. Some of the non-musicians and musicians who were not ear trained displayed extremely low differences of informational masking. Their differences were even lower than those of the trained musicians. This pattern has also been observed previously by both Oxenham and Lutfi.

t-tests were run to determine if any of the differences between groups were significant. Each group was compared to the control group in turn. Then the control group and the untrained listeners were compared to the trained musicians and Morse code operators as a group. None of the scores were statistically significant. Too much variability existed within each group for any of the results to be significant. The averages were not very stable in any of the groups. Please refer to the tables below.

Table 2

	T value	P value	Degrees of freedom	Statistically Significant?
Control vs. Non Expert Musicians	.16197	.87491	9	No
Control vs. Expert Musicians	.85296	.85296	8	No
Control vs. Morse Code Operators	-.62669	.55074	7	No

The chart above lists the T value, P value and degree of freedom for each of the t-tests run. None of the results were statistically significant.

Table 3

	T value	P Value	Degrees of freedom	Statistically significant?
Non Expert listeners vs. Expert Listeners	-.16056	.87445	16	No

The graph above lists the T value, P value and degree of freedom for the t-test run. The non-musicians and the non-expert musicians were grouped together to form the Non Expert listening

group. The Expert Musicians and the Expert Morse code Listeners were grouped together to form the Expert listening group. The results were not statistically significant.

IV. Discussion:

Overall, the experiment was successful because it replicated Dr. Oxenham's study and generated new results for the Morse code group. The results contradicted the hypothesis that the trained listeners would perform better by attaining lower threshold differences.

Several factors may be acting as confounds and need to be considered when examining the results. First, all of the test groups were very small. Larger test samples are necessary for more stable averages and results. Age differences are also a problem. The expert listening groups are significantly older on average than the inexperienced groups. Some of the older participants had a sloping hearing loss in the upper frequencies. This should not be a confound though because most of the auditory information fell around 1000 Hz. The group of trained musicians who passed the interval test and the group of Morse code listeners were older on average than the control group or the first group of musicians. Expert listeners were very difficult to contact for this study. Very few were available or willing.

The rest of the problems pertain to the Morse code group specifically. The test group contained only three people. This is not a large enough sample size. The group was also very homogenous. All three Morse code operators were middle-aged males. This may have been irrelevant, but many of the older participants had high frequency hearing loss. All of the participants had normal hearing at the one thousand Hz range where the target tone was though.

Another confound may be that both music and Morse code are processed in different parts of the brain than pure tones. Morse code specifically is processed differently than pure tones because it requires language. That type of listening skill might be too different from the experiment task for any results to show. Music, on the other hand, is at least still tones that are being processed. It was still surprising that the Morse code operators did not perform better because some trained in conditions that should have been conducive to performing well on this task. Some of the participants listened to Morse in back ground noise. Others trained to listen to one strand of Morse code playing simultaneously with many other messages. Each message plays at a different frequency and the Morse code listener must be able to pick out their specific frequency. This task should have been excellent training for performing well in the MBS masking task especially.

More research on this topic with larger, more uniform groups should be conducted for clearer results.

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